Results from the BA 50 Balanced Scheduling Strategy INT01 R&Ds

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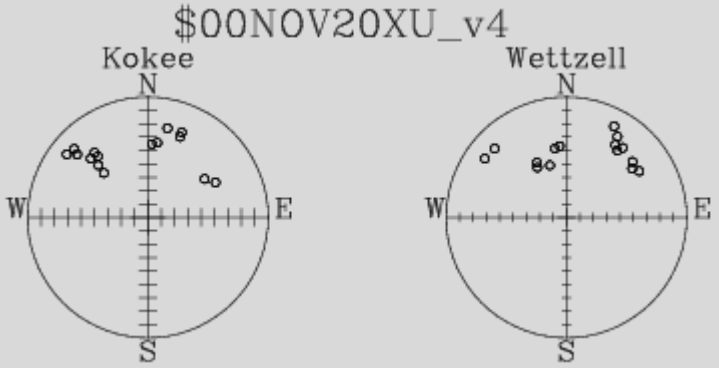
Outline

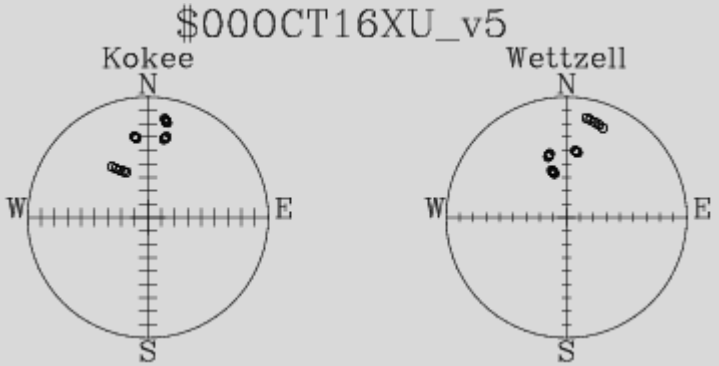
1. "**STN**": the original INT01 source list (**strong** but **few sources** and **bad** source **coverage**, leading to **high** UT1 formal **errors** at some times of the year).
2. "**MSS**": the 2009 INT01 source list (**all sources** and **best** source **coverage**, so original problem was solved but **weak**, leading to increased UT1 formal errors at new times of the year (formal **error tradeoff**)).
3. "**BA 50**" (Balanced 50): proposed INT01 source list (**intermediate** number of **sources** (50), **intermediate** source **coverage** and **intermediate strength**).
4. Six R&Ds that tested the BA 50 and its effect on the UT1 formal error.

Original Source List: STN

INT01 UT1 formal error / observation sky coverage pattern
Excerpt from Baver et al., 2004 GM proceedings paper



15 successful observations
32 ps session fit
12.66 µs UT1 formal error

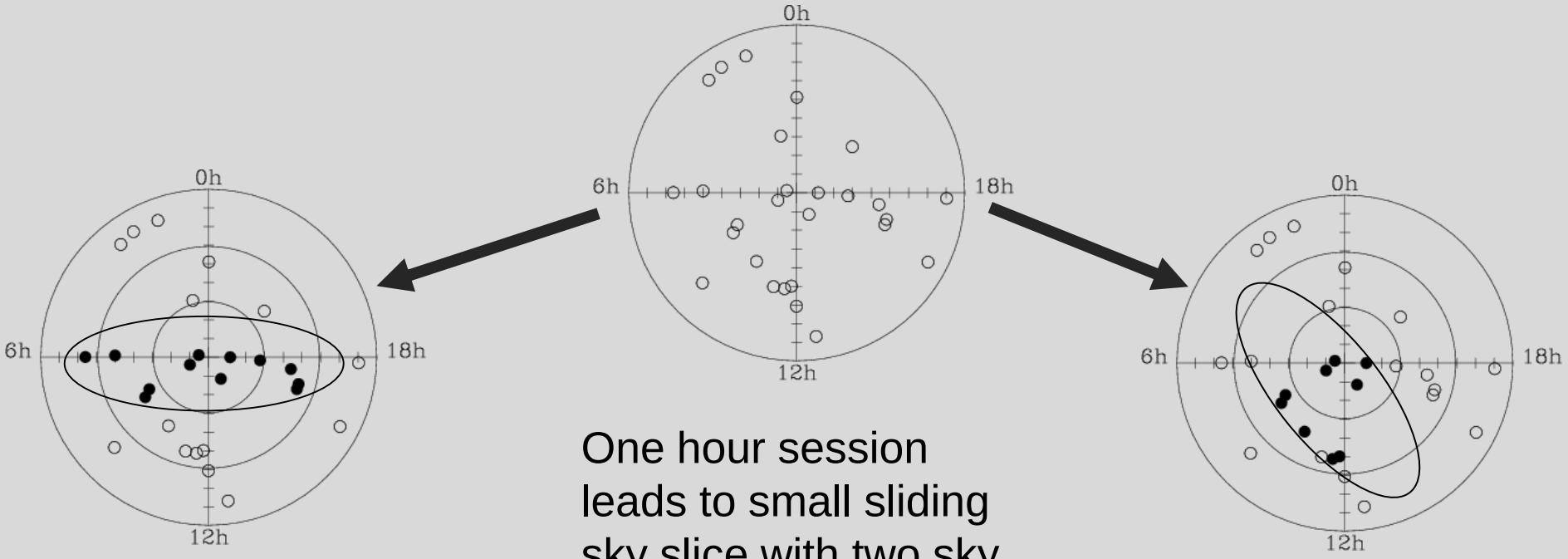


15 successful observations
31 ps session fit
48.97 µs UT1 formal error
(very high: 20 µs is highest usable value)

Noted as one example of an empirical general connection between wider sky coverage and smaller UT1 formal errors
Later independently studied in more depth (and confirmed) by Uunila et al.: 2012 GM, 2013 EVGA

Original Source List: STN

Meanwhile we also saw a seasonal effect and (in 2006) cause:
INT01 Source List (**"STN"**)
Few sources (varies: as low as ~ 30), strong, but uneven



Early November: **wide** source and observation coverage (Uunila's cusp observations)
Low UT1 formal errors

One hour session leads to small sliding sky slice with two sky coverage extremes shown in the mutual visibility ovals

Early October: **narrow** source and observation coverage (no cusp observations)
High UT1 formal errors

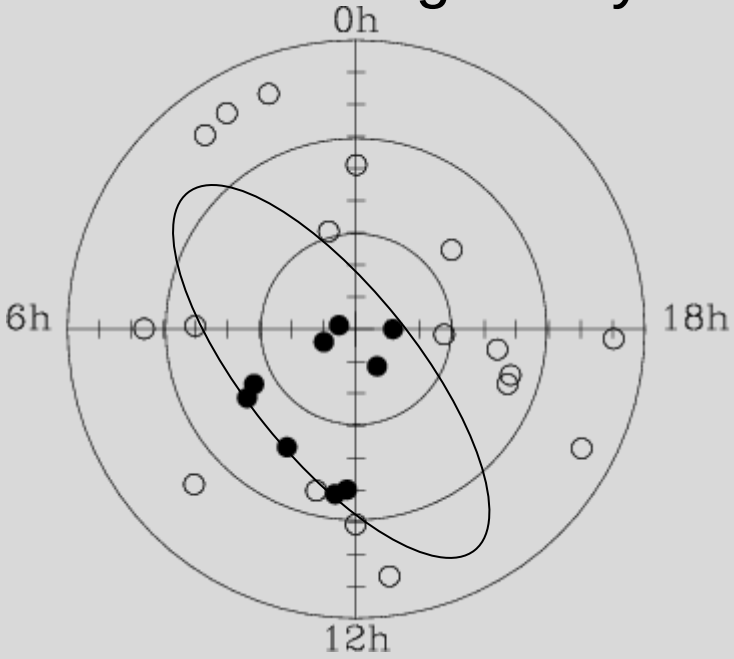
Second (2009) Source List: MSS

2009: MSS (Maximal Source Strategy)

STN: few (>= ~30) sources

Source coverage: sparse
Uneven with gaps

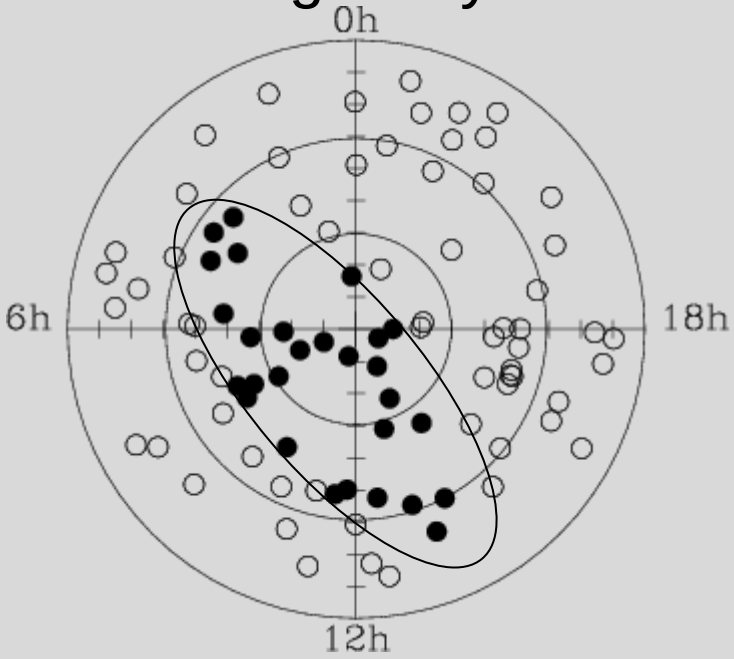
Narrow coverage early Oct



MSS: all (~ 90) geodetic sources

Source coverage: maximum
More even but clumps

Wide coverage all year



Early October UT1 formal errors are greatly reduced

Second (2009) Source List: MSS

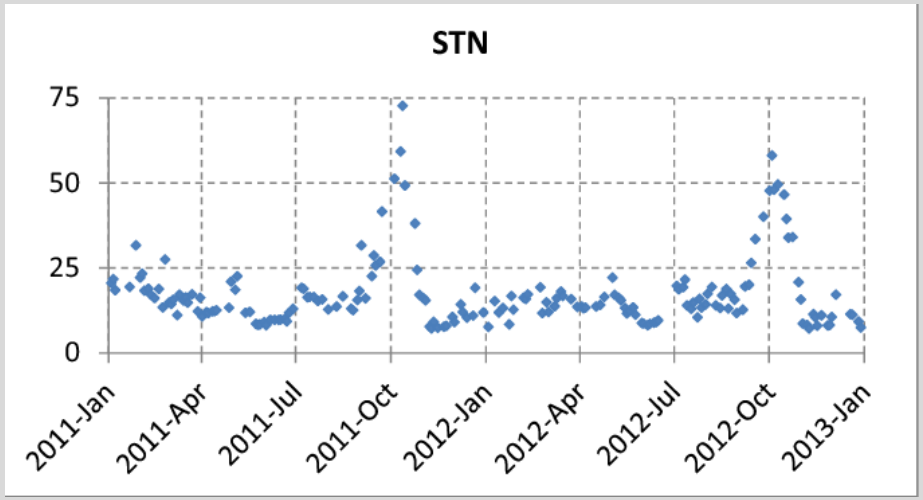
Testing: The use of all geodetic sources was tested in nine 2009/2010 IVS R&D sessions.

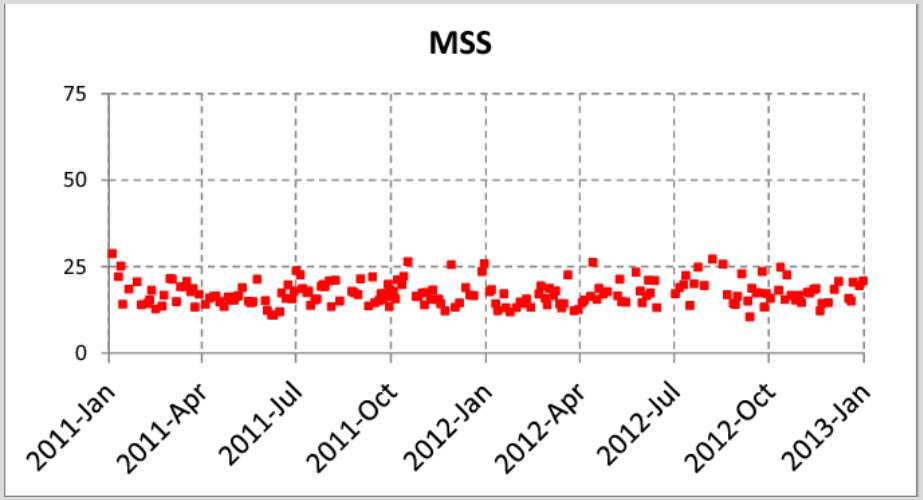
Operational use:

2000 to mid 2010	mid 2010 to mid 2016	mid 2016 to now
STN	**STN/MSS**	**MSS**

Second (2009) Source List: MSS

Observed UT1 formal errors from 2011/2012 alternating operational STN/MSS *





observed UT1 formal error µs *	STN	MSS
First half Oct	32.0	15.1
First half Nov	10.0	12.0

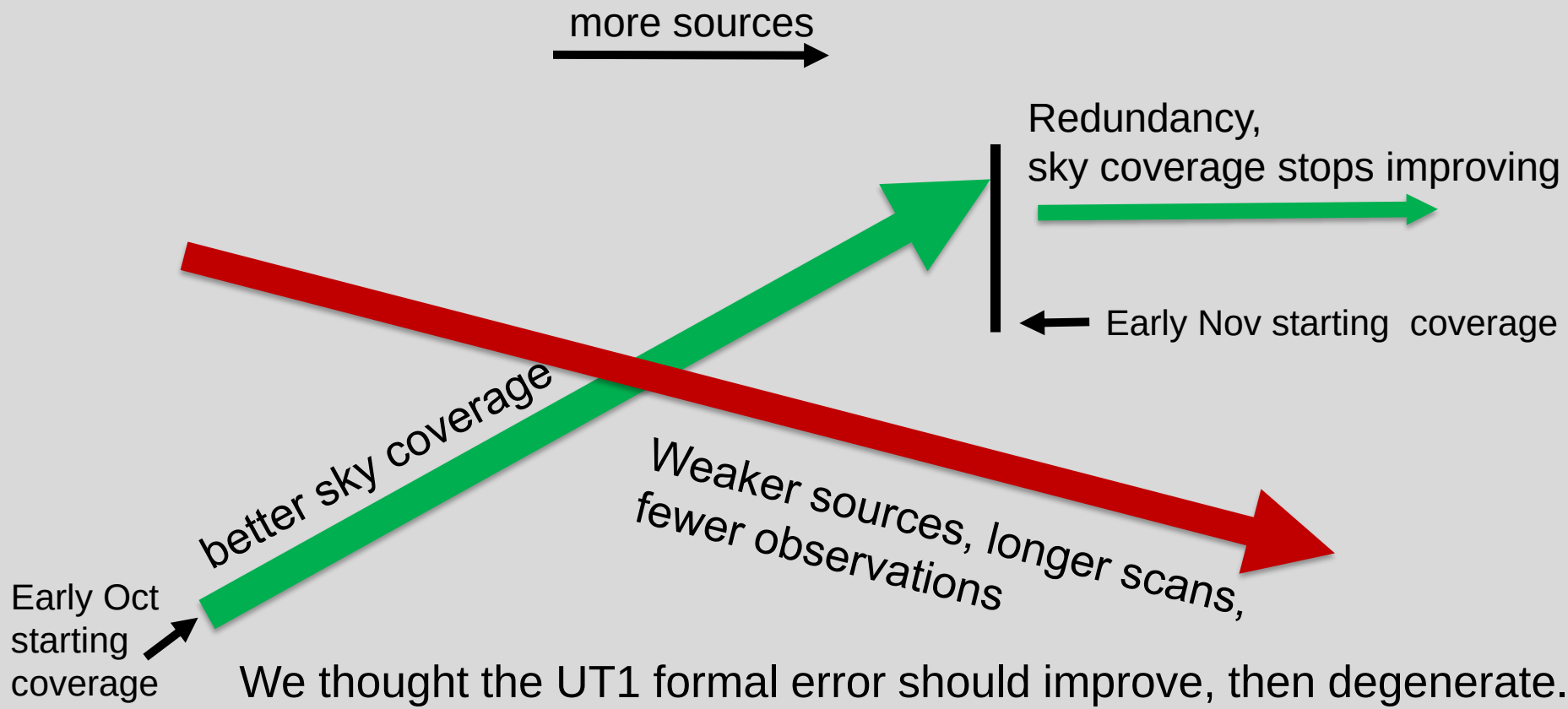
MSS provides great October improvement but could use a little refinement for November

* From Gipson and Baver, 2016

Second (2009) Source List: MSS

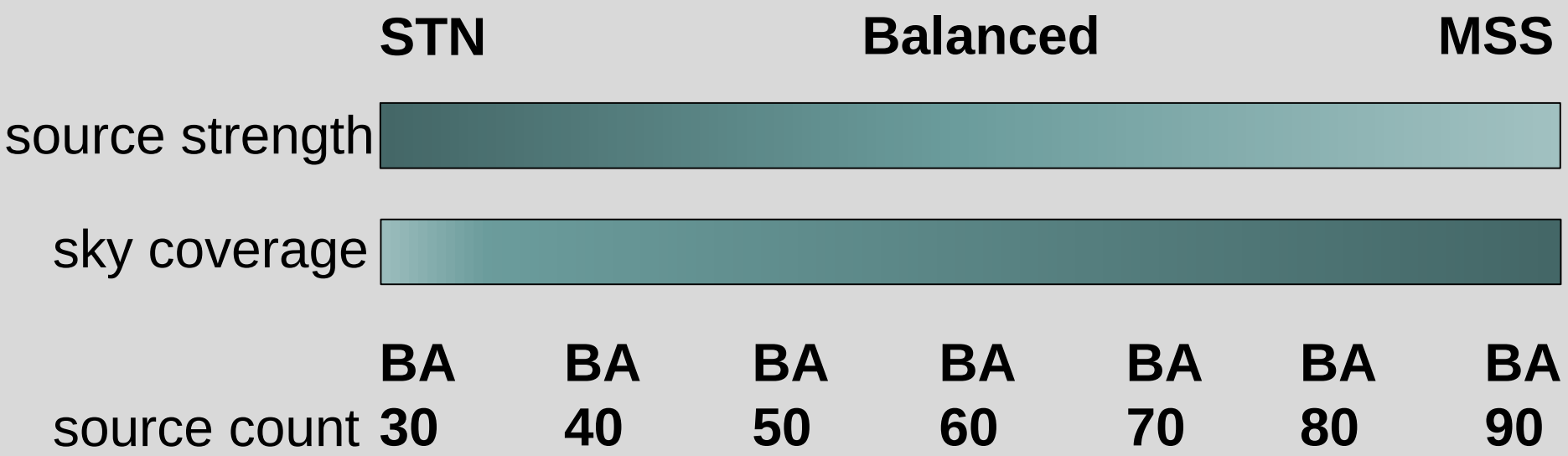
Why does the early November UT1 formal error increase?

2014 explanation: UT1 formal error tradeoff



We thought the UT1 formal error should improve, then degenerate.
We wanted to find a balancing point.

New, Balanced Source List: BA 50



Add enough sources to help early October….

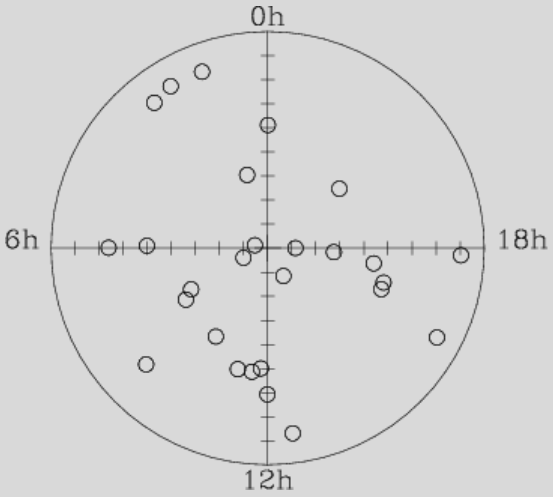
but not enough sources to hurt early November.

(Actually, did not add sources;
instead used Sked to create new, balanced source lists.)

2014 --- 2016 **Simulations** → **Selection of BA 50**

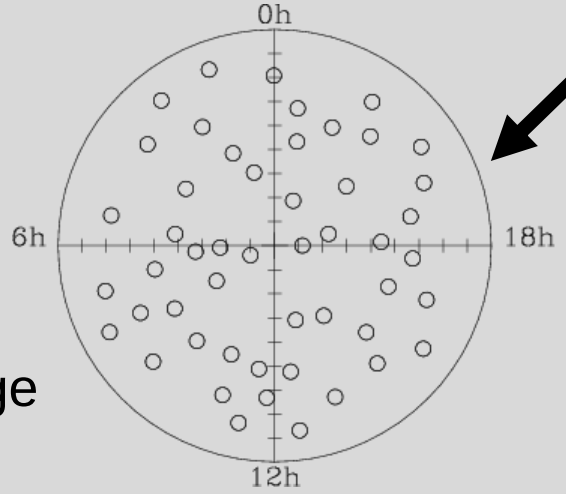
New, Balanced Source List: BA 50

STN >= ~**30** sources

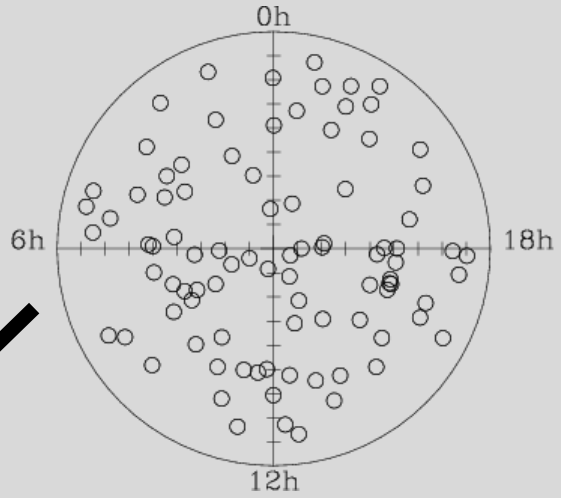


Strong BUT
Uneven coverage, **gaps**
Seasonally narrow coverage

BA 50
50 sources



MSS ~ **90** sources



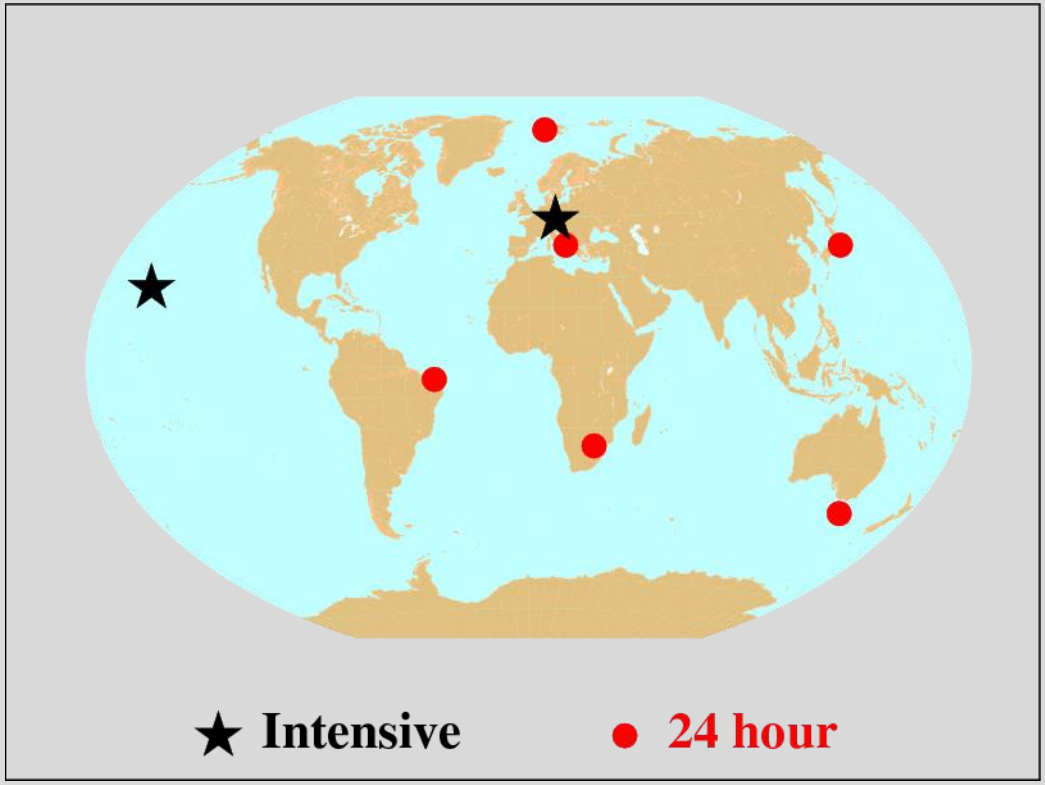
wide coverage all year
BUT **weak**
Redundant coverage

Generally even, wide, coverage
minimized gaps and redundancy,
AND **intermediate strength**

BA 50 R&Ds: Design

We tested the BA 50 in six 2016/2017 R&Ds.

Two independent networks



● sample 24 hour network --- stations varied

★ **WETTZELL, KOKEE**: 24 one hour **Intensives** per R&D

● **Remaining stations**: **24 hour** session providing an independent check on UT1.
Only criterion: long east/west baselines

BA 50 R&Ds: Design

144 one hour intensive R&D sessions

GST	= observing around	RD 1608	RD 1610	RD 1701	RD 1702	RD 1706	RD 1707
00:00	December 13	MSS	BA 50	MSS	BA 50	MSS	BA 50
01:00	December 28	BA 50	MSS	BA 50	MSS	BA 50	MSS
				. . .			
19:00	September 27	BA 50	MSS	BA 50	MSS	BA 50	MSS
20:00	October 13/14	MSS	BA 50	MSS	BA 50	MSS	BA 50
21:00	October 28/29	BA 50	MSS	BA 50	MSS	BA 50	MSS
22.00	November 12	MSS	BA 50	MSS	BA 50	MSS	BA 50
23:00	November 27	BA 50	MSS	BA 50	MSS	BA 50	MSS

72 MSS, 72 BA 50 overall

3 MSS, 3 BA 50 per GST

BA 50 R&Ds: Results (Average)

Predicted UT1 formal errors

µs	MSS	BA 50
Avg	7.88	6.46
STDev	1.53	0.99

Improvement:
average 1.4 µs (18%)
st. dev. 0.5 µs (33%)

Observed UT1 formal errors

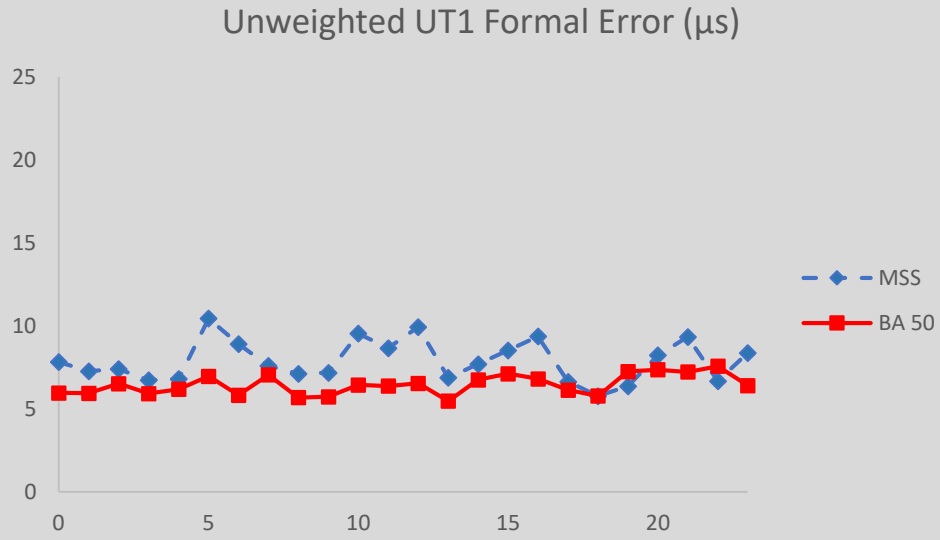
µs	MSS	BA 50
Avg	13.36	10.85
STDev	6.34	5.25

Improvement:
average 2.5 µs (19%)
st. dev. 1.2 µs (17%)

Promising results.

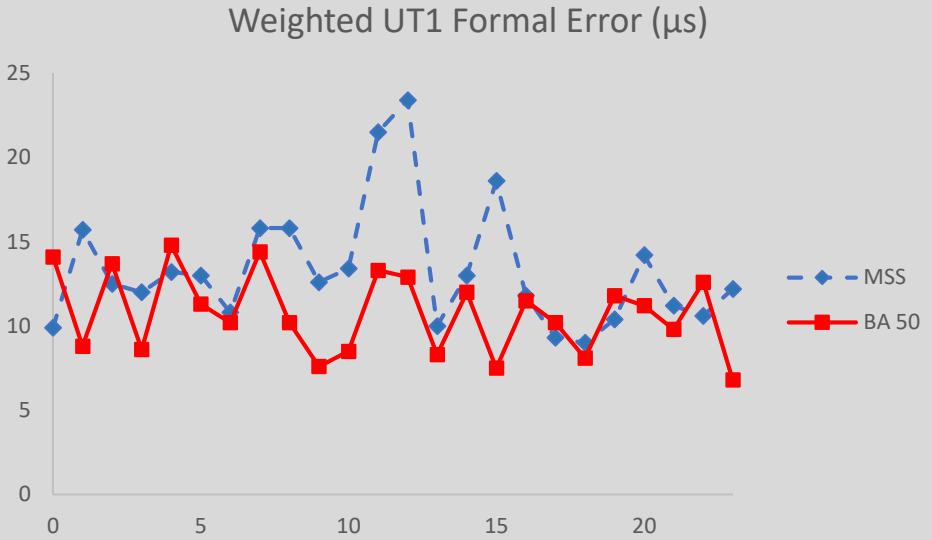
BA 50 R&Ds: Results (by GST)

Predicted UT1 formal errors



BA 50 is
- better: 21 GSTS
- equal: 1 GST (18)
- worse: 2 GSTS (19, 22)

Observed UT1 formal errors



BA 50 is
- better: 17 GSTS
- equal: 1 GST (16)
- worse: 6 GSTS (0,2,4,17,19, 22)

Preliminary results: with only three MSS/BA 50 pairs, more testing is needed.

For now, the more significant, predicted UT1 formal errors are promising.

USNO is interested in alternating MSS/BA 50 testing.

Conclusions

- The BA 50 average UT1 formal error shows promising improvement.
- More GST-based testing should be done.
- Other metrics such as accuracy must be evaluated.
- Based on the improvement in the UT1 formal error averages, USNO is interested in alternating MSS/BA 50 testing.

Acknowledgements

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BA 50 R&D Sessions

Questions & Comments

Thank you.

Questions?